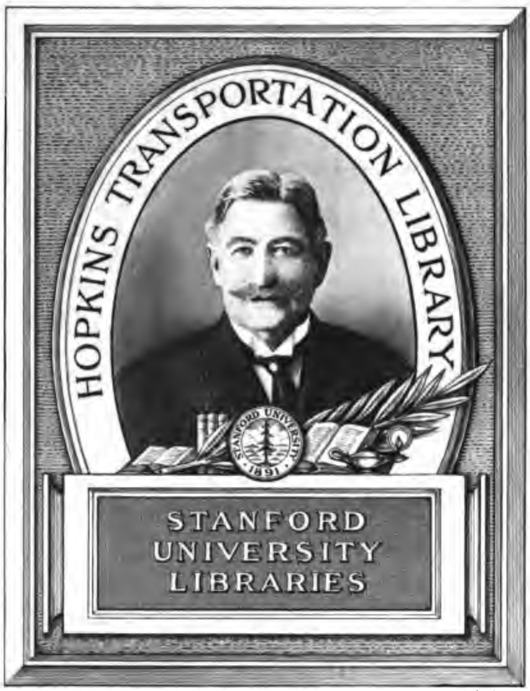
THE SOUTH DEVON
ATMOSPHERIC RY.

SIR F. BRAMWELL

1899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# SOUTH DEVON ATMOSPHERIC RAILWAY,

PRECEDED BY CERTAIN REMARKS ON

# THE TRANSMISSION OF ENERGY BY A PARTIALLY RAREFIED ATMOSPHERE.

BY

SIR FREDERICK BRAMWELL, BART., D.C.L., LL.D., F.R.S.,
PAST-PRESIDENT.

EXCERPT MINUTES OF PROCEEDINGS
OF THE MEETING

OF THE

INSTITUTION OF MECHANICAL ENGINEERS,
IN PLYMOUTH, 25TH JULY 1899.

SIR WILLIAM H. WHITE, K.C.B., LL.D., D.Sc., F.R.S., PRESIDENT,
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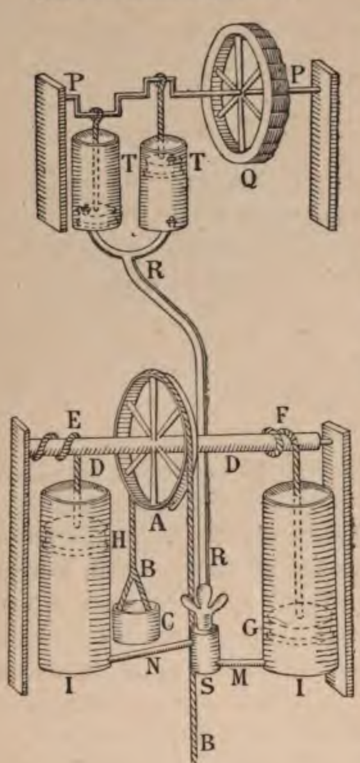
# THE SOUTH DEVON ATMOSPHERIC RAILWAY, PRECEDED BY CERTAIN REMARKS ON THE TRANSMISSION OF ENERGY BY A PARTIALLY RAREFIED ATMOSPHERE.

By Sir FREDERICK BRAMWELL, Bart., D.C.L., LL.D., F.R.S.,
*Past-President*, of London.

Leaving out of consideration Savery's and such like machines for the raising of water by means of a partial vacuum produced by the condensation of steam—the first suggestion, so far as the writer is aware, for transmitting energy by the rarefaction of air, was made by Denis Papin, who, in 1695, published in Cassel a book called "Recueil de diverses piéces touchant quelques nouvelles machines," where, at page 36, is to be found the description of the drawing, Fig. 1, page 300.

Without repeating Papin's minute description, it will suffice to say that the waterwheel Q, by means of the double-throw crank-shaft P, worked two exhausting pumps T T, from which proceeded the common exhaust-main R to the place where the power was required to be developed. Here there were two open-topped working cylinders I I, containing pistons H G, on the under side of each of which a partially vacuous condition was, from time to time, to be made by connecting their respective pipes N and M alternately with the exhaust main R and with the atmosphere, by the operation of the central cock S. The pistons had ropes E and F attached to their upper sides; these ropes were wound in reverse directions around the axle D, which axle carried the large grooved wheel A, having over it the rope B, at each end of which were the buckets C, to raise the water.

FIG. 1. *Denis Papin*, 1695.

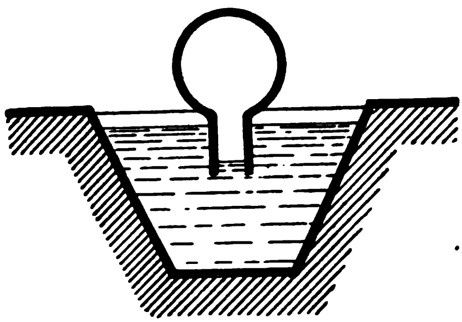



Papin says that such an apparatus, if he is not deceiving himself, will serve much more readily than any hitherto invented, to transport the force of rivers into places at considerable distances; to there draw water from mines, and to do other works which require much labour. At page 41 he says, one may find some means so that the machine itself will turn the cock S at the needed time; but he thinks it will be better to have a man to do this job, who will also be employed to empty the buckets as they come from the mouth of the mine.

It is extremely likely that, in the 115 years which elapsed between Papin's publication and the year 1810, there may have been propositions for the transmission of energy by air-pressure, but the writer has not come across them, and, so far as he knows, the matter lay in abeyance until that year (1810), when Mr. G. Medhurst proposed the propulsion of trains within a tube of 30 feet area, 6 feet high by 5 feet wide, by a pressure (not a rarefaction) of about 16 lbs. per square foot.

He says that this will be an adequate force to drive the air 50 miles an hour; but to propel the load he allows an addition of about 13¼ lbs., or something under 30 lbs. to the square foot, to move the air and the load of the train at 50 miles an hour. This he says can be done by a 180 H.P. engine.

FIG. 2. *Medhurst.*



Then he says: "In many cases it will be practicable upon the same principle to form a tube so as to leave a continual communication between the inside and the outside of it, without suffering any part of the impelling air to escape, and by this means to impel a carriage along upon an iron road in the open air with equal velocity, and in a great degree possessing the same advantages as in passing with-inside of the tube, with the additional satisfaction to passengers of being unconfined and in view of the country."

Then he proposed to employ a 12-inch tube.

It appears from a subsequent pamphlet that the mode by which he intended to make communication between the tube and the exterior was by a water seal, Fig. 2, but apparently he had discovered that the air-pressure of 3 lbs. and 6 oz. per square inch —that which he had assigned to a 12-inch tube—would be rather difficult to retain by a water seal, and he then proposed to use a 24-inch tube.

In this later pamphlet (1827) he suggested a rectangular iron tube, with a wrought-iron or copper "semi-top," as he called it, riveted to the flange and lifted by the projection of a wheel attached to the piston, and thus admitting the protrusion of an arm to connect the piston inside the tube with the external carriage. There is not any description of how the valve was to be closed and sealed.

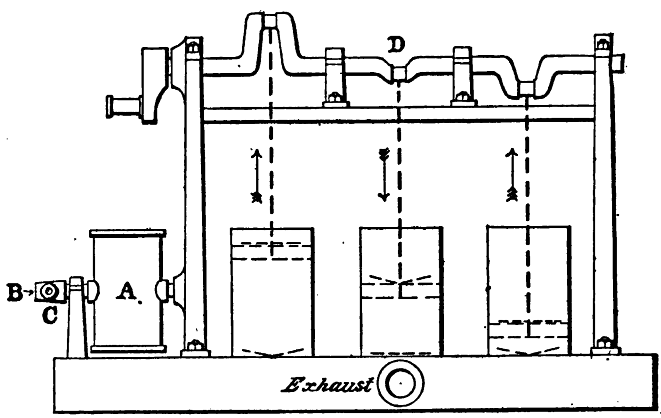
The writer has come across the name of Lewis as having done something with atmospheric transmission of energy in 1817, but he has not been able to trace the particulars of that which Lewis did.

In 1824, however, John Vallance took out his patent, No. 4905, so very well known to all who have interested themselves in this subject of transmission of energy by the pressure of the atmosphere.

Except that Vallance proposed to move his train by the rarefaction of the air, his scheme was a mere repetition of that of Medhurst already mentioned.

But the man who really developed this mode of transmission of energy was John Hague, to whom the writer was apprenticed.

FIG. 3. *Hague*, 1827.




Hague took out a patent, No. 5546, 1827, Figs. 3 and 4, wherein he proposed to have a proper number of exhausting pumps, working continuously and maintaining continuously a partial vacuum: a pipe was laid from the pumps to the place where the power was needed to be used, and he placed there an engine of the character of a steam engine, which engine was put to work by the pressure of the atmosphere upon the piston of the engine, on the other side of which piston there was the partially vacuous condition.

This system was very extensively followed.

In the year 1836, Hague took out a second patent, No. 7088, Fig. 5, for raising water by the use of a partially-vacuous condition. His plan was to have a succession of shallow cast-iron reservoir boxes placed, either in a shaft or on an incline, at vertical heights of about 20 feet apart, and to connect these boxes by rising water-mains, and also to connect them to an exhaust main. Say, for example, six boxes were to be used on the incline shown, and imagine

FIG. 4. *Hague*, 1827.

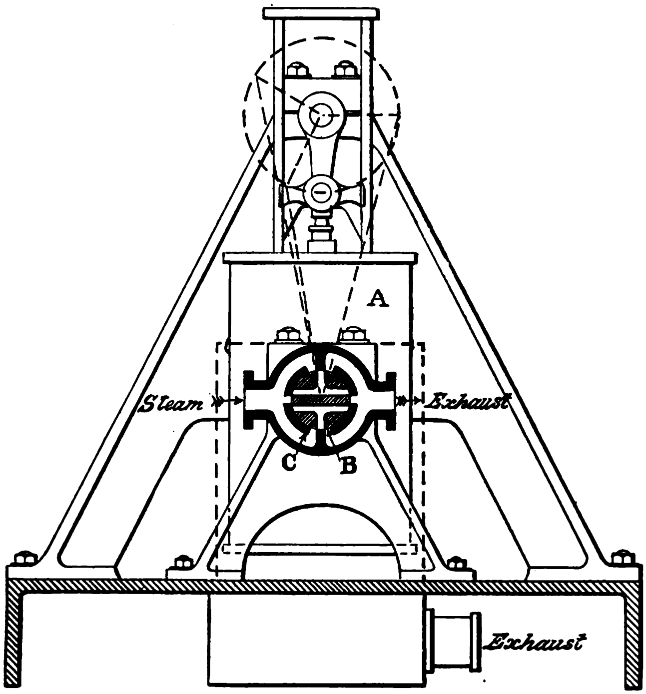
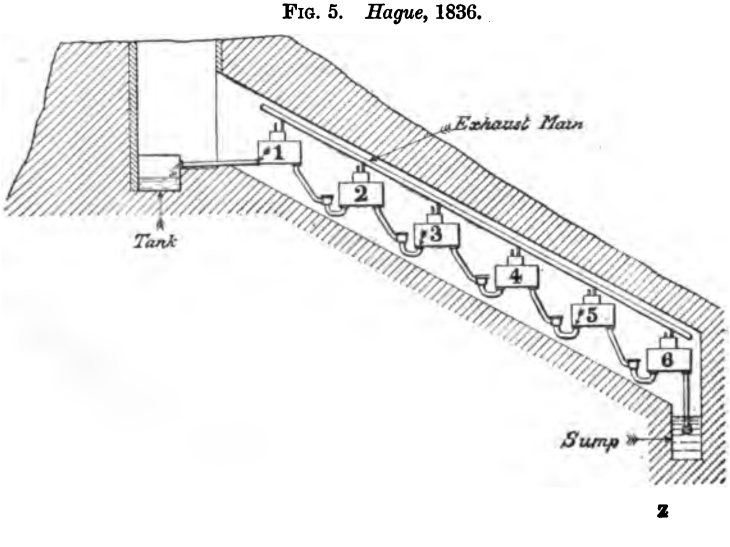



FIG. 5. *Hague*, 1836.

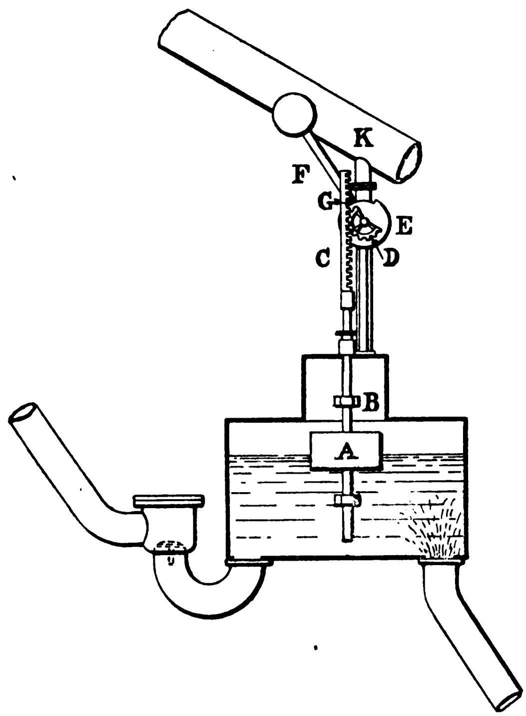


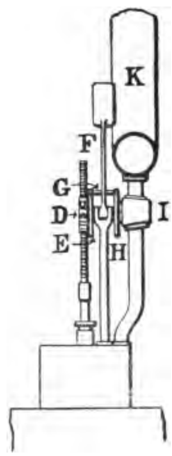
that Box 1, at the top, was delivering its water into a tank at the top of the incline; then Box 3, at the same time, would be delivering its water into Box 2; Box 5 would be delivering its water into Box 4, and Box 6 would be drawing its water from the sump. As soon as 1, 3 and 5 were empty, and 6, 4 and 2 were full, the connections of 2, 4 and 6 with the exhaust main were automatically closed, and connections were made for these boxes with the atmosphere; while, at the same time, and automatically, connections were made between Boxes 1, 3 and 5 with the exhaust main. These boxes *at once* began to fill from their immediately lower Boxes 2, 4, and 6, by reason of the water being forced up into them by the air-pressure. The merit of this invention was, that the boxes could be placed on an incline equally well as in a vertical shaft, and that they could be worked by a quiescent exhaust-main instead of by heavy moving rods, as in the case of pumps. The defect was that, while the vacuous condition must be such as to raise the water from the very bottom of an emptying box to the very top of a filling box, the mean effective lift was only the distance apart from centre to centre of the two boxes; thus there was a large amount of extra lifting, which produced no good result. Moreover, in practice (for these boxes were put to work), they failed to synchronize, and in this way the "pitch" in working was not kept up.

Figs. 6 and 7 show the method that was adopted to make the automatic reversals between the boxes and the vacuum main and between the boxes and the atmosphere.

As a box filled, its float A rose, and striking the stop B, raised the rod connected to the rack C, turning the pinion D, and with it the disc E, raised the loggerhead lever F, by means of the pin G, bearing against the edge of the notch in the disc E, until it assumed, just before the box was full, the vertical position. The last filling of the box took place very sharply in consequence of the rise of the float into the tubular top on the box, which top the float nearly fitted; thus the loggerhead F was thrown past the centre, and then its pin G ran away from the side of the notch which had been driving it, and the loggerhead fell; in falling, the other end of the pin G struck the notch-plate H, on the plug of a cock I, a blow, and rapidly

FIG. 6. *Hague*, 1836. FIG. 7.



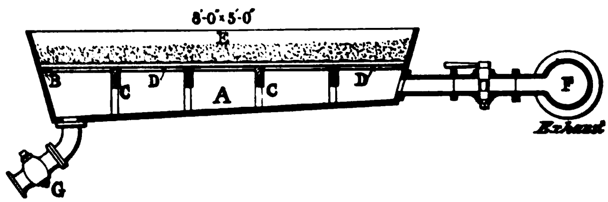




reversed it, cutting off the connection with the exhaust-main K, and making connection with the atmosphere. As the box emptied into the one above it, the reverse operation took place, so that when the box was empty the connection with the atmosphere was shut off, and that with the exhaust-main was re-made.

A previous use that Hague had made of a partially vacuous condition was one that can hardly be called, in the usual sense of the term, "transmission of energy," but it was very ingenious, and its insertion here may perhaps be permitted. In the year 1816 he took out a patent, No. 4048, for purifying sugar by means of partial exhaustion. The readers of this Paper are begged not to confound this with Howard's Vacuum Pan, which was a contrivance for boiling

off, by the aid of steam-heat, the needed amount of water from the sugar solution, but doing it at a low temperature by reason of the highly vacuous condition in which the ebullition was effected. Hague employed no heat in his process at all.

FIG. 8. *Hague*, 1816.

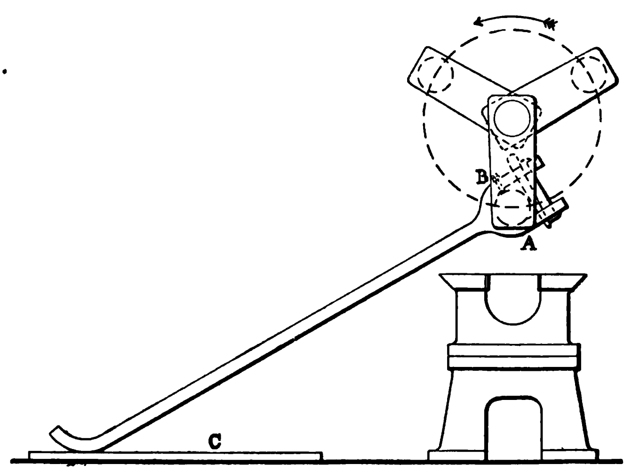



He used a cast-iron pan, such as A, Fig. 8, having a small internal flange B about half-way up, which flange, with the aid of a wooden framework C, supported a frame D, which carried a perforated copper surface surmounted by a hair cloth. On this cloth, the coarse sugar E, was filled in, extending quite up to the sides of the pan three or more inches deep, care being taken to lay it uniformly, so as to leave no particular air-channels; and then, on opening connection with the vacuum main F, a partially vacuous condition was produced below the hair cloth, and the pressure of the air drove the colouring matter, which had been adhering to the crystals, through into the lower part of the pan. This operation was facilitated by sprinkling the sugar either with water or with a white sugar solution. When the crystals had been cleaned, the communication with the exhaust main was shut off; air was admitted, and the molasses which had collected in the bottom of the pan was drawn off by the cock G.

Large numbers of these exhausting apparatus and pans were made. The ordinary form of the engine and pumps used for these apparatus was that shown in Figs. 3 and 4. A high-pressure oscillating cylinder A made its inlet and exhaust by means of a cone B on the cylinder working in a shell C. The writer does not put this forward as an economical engine; but he adduces it as a simple one. The engine worked a 3-throw crank-shaft D, Fig. 3,

made in cast iron. The strokes given by this crank-shaft were not uniform within one-eighth, or it might be within one-quarter of an inch, for the mode of turning the pins of the throws was simple, but not exact. The 3-throw shaft, Fig. 9, was "chucked" in the lathe upon its centres. Then an implement A, somewhat like a connecting-rod, was put round the throw of which the pin was to be turned. This connecting-rod, so far from being furnished with a brass, was furnished with a cutter B. The prolonged tail of the connecting-rod slid backwards and forwards on a boiler-plate C, laid on the floor. The cutter B was screwed up as needed, with the result that practically round crank-pins were obtained without the necessity of "re-chucking" the shaft upon each one of the crank-pins. This mode of turning was called by the men "Fox-chasing."

FIG. 9. *Three-Throw Crank-shaft.* "*Fox-chasing.*"



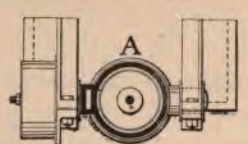

There were foot-valves in the bottoms of the pumps, and corresponding valves in the buckets, but no head valves, the pumps being open-topped. These engines, as has been said, were very simple; they could be worked by the most ignorant "black" on a sugar estate, and, except on the score of fuel economy, they did their work very well.

When the partial exhaustion was employed—neither for purifying sugar, nor for the direct raising of water, but for driving a motor—that motor was a repetition of the oscillating steam engine, Fig. 11. There was, in the very early days of distribution of energy, a large field open for this particular mode. Hague made a very pretty model of an ordinary wharf crane, and showed it working and raising weights, while the exhaust pump was in another room, the connection being made by a pipe.

Figs. 10 to 14 are taken from the crane drawing attached to the specification of Hague's patent, No. 5546, 1827. Fig. 10 is a

*Oscillating Cylinder. Hague*, 1827.

FIG. 10.



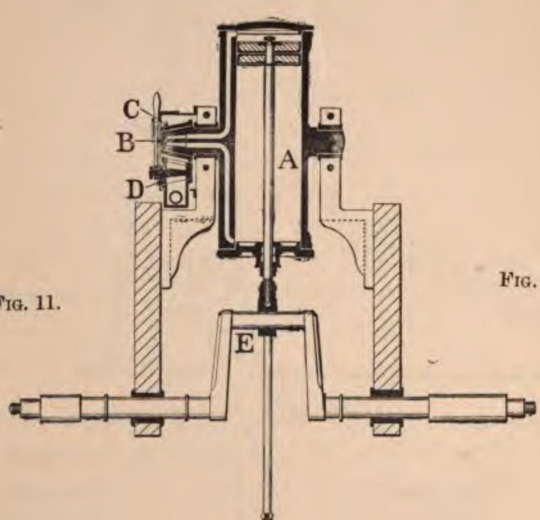




FIG. 11.

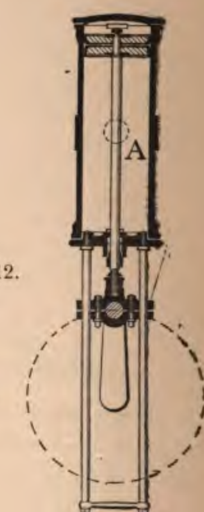



FIG. 12.

sectional plan. Fig. 11 shows a section of the oscillating cylinder A, with its cone B, working in the shell C, having beneath it the reversing cock D. The great length of the crank-pin E, was to admit the usual endway motion of the shaft to vary the speeds of the gear. Fig. 12 is a transverse section. Fig. 13 is a section through the cone B, shell C, and reversing cock D. Fig. 14 is an external elevation of these parts. The model and the explanation of how the crane would thus be worked from a central steam-engine impressed the directors of the St. Katharine's Docks very much, and they were quite disposed to accede to Hague's proposition to do the work of these docks by means of the pneumatic cranes, instead of by the

*Oscillating Cylinder, Hague*, 1827.

FIG. 13.

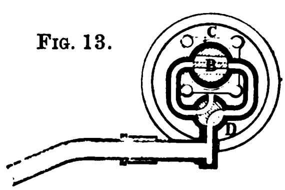
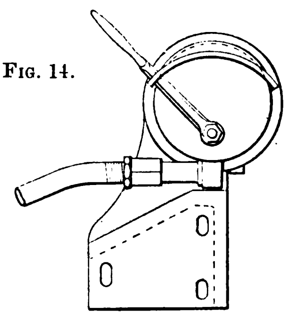



FIG. 14.



tread-wheels, then in use at the adjoining London Docks. But Hague, whose ingenuity was undoubted, never kept his promise as regards time, and the result was that this chance of working the cranes of a dock from a central steam-engine driving exhausting pumps was lost to him.

Such cranes were put to work later on at Whitstable, and continued to be employed there for very many years; indeed until 1886.

A few similar cranes were erected at London Bridge Station.

At one time (date forgotten) the Admiralty were prepared to make an experiment in driving the various machine-tools at Woolwich Dockyard by means of partial exhaust engines applied to each tool, thus dispensing with line shafting.

The writer refers to Fig. 15, which is a reduction of the original sketch, made by him for the guidance of the draughtsman, in preparing the drawing for certain of these dockyard engines.

Fig. 15. *Partial Exhaust Engine.*

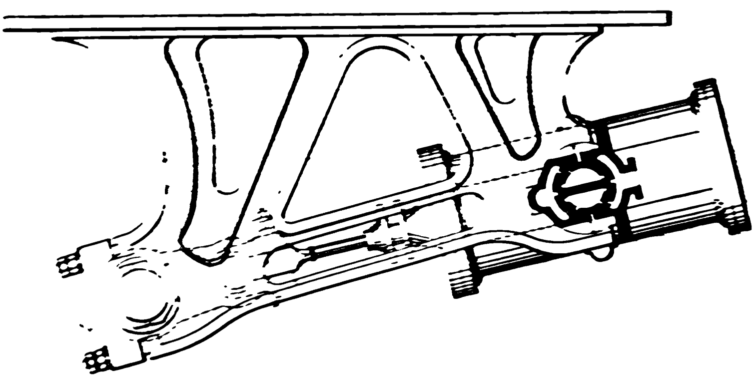
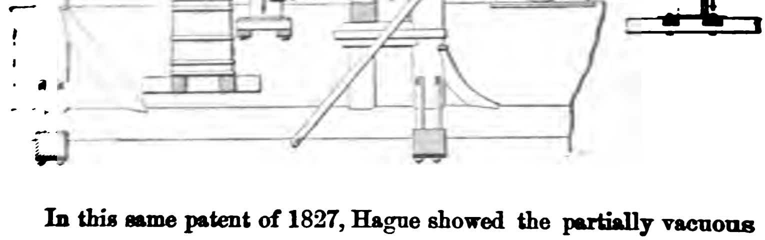


Fig. 16. *Pneumatic Tilt Hammer. Hague*, 1827.



In this same patent of 1827, Hague showed the partially vacuous condition applied to a tilt hammer, Fig. 16. The writer, when an apprentice, saw a small tilt of this kind, intended for planishing the bottoms of frying pans and such like matters, put to work, with

the result that the hammer disappeared. The reciprocations were many hundreds a minute, and thus the outline of the hammer was entirely lost, and nothing but a mere " blur " resulted.

Hague applied this mode of transmitting energy to driving the machinery of powder mills, so as to remove the danger of steam-engine fire to any distance needed for safety. He also applied it to work the individual cutting-out presses and coining presses of a mint which he constructed for Rio Janeiro.

When working the motors by the pressure of the air seeking entrance into the partially vacuous cylinder, it was found that long before the freezing point was reached in the ordinary atmosphere, icicles would form about the nozzles of these motors. This was a source of considerable astonishment. It was also found that in the top of the air-pumps already mentioned, the air came out of the piston-valves very sensibly warmed. In those days, this warming was attributed to friction; but, owing to the pumps being open-topped, there was so great a circulation of atmospheric air that the temperature never rose to any inconvenient point. When, however, air-pumps were applied to the beams of steam engines, and were made double-acting, then the increase of temperature made itself inconveniently felt, and the writer devised a means of reducing this, by introducing a small injection of cold water at the two ends of a double-acting air-pump.

It did not occur to anyone to take indicator diagrams from the pumps, either with or without the injection; but it was found that, with the injection, the steam-engine driving the pump would make about 10 per cent. more revolutions when the injection was on than when it was shut off, the vacuum being equal.

The writer has thought that the foregoing might be interesting, as leading up to the subject of Atmospheric Railways, and also as setting forth the work of a man, John Hague, in the way of conveying energy by the rarefaction of air, who was the master to whom Jacob Samuda, who did so much to endeavour to develop Atmospheric Railways, had been apprenticed, and who, under Hague, had been thoroughly imbued with the system of transmission of energy by partial exhaustion.

Some years later, 1846 to 1850, the writer conceived the idea that Vallance's system would be peculiarly applicable for Subterranean Railways in London, which railways he proposed to carry down well into the London clay, and thus to obtain a good stratum in which to work, and also a position below and clear of all the sewers and other matters situated a short distance beneath the surface. He proposed to make a rectangular tunnel, Fig. 17, large enough to contain a first-class railway-carriage body, the wheels being at the ends of the carriage, the body hanging down below the axles, and to make this rectangular tunnel entirely of cast-iron plates. The railway was originally designed by him to extend from Charing Cross to the Bank, but subsequently it was proposed to carry it to Hyde Park Corner. At the City end, its station was to be in certain property (poor property in those days) at the back of the Old Jewry; and the writer, in conjunction with his late fellow-apprentice, Mr. Homersham, and an architect, Mr. Boulnois, worked out the system, including the method of taking passengers up and down by means of hydraulic lifts, Fig. 18. The writer sufficiently impressed a firm of solicitors with the merits of the idea, as to cause them (he believes in 1846) to prepare the requisite parliamentary notices for making a sample railway of this kind over the then Hungerford Suspension Bridge, Figs. 19 to 21, page 314, so as to carry passengers backwards and forwards between the South Western "Waterloo" Station and a station to be made in Hungerford Market, but the matter went no farther.

FIG. 17. *Proposed Hyde Park and Bank Subterranean Railway.*

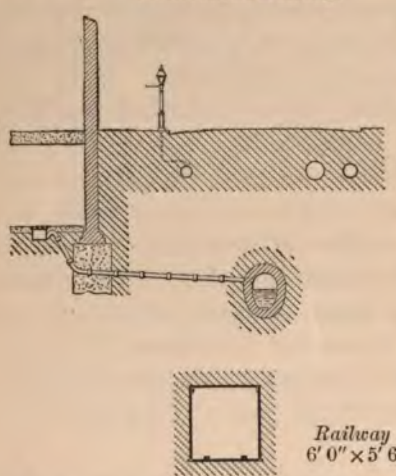


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FIG. 19. *Hungerford to Waterloo*, 1846.

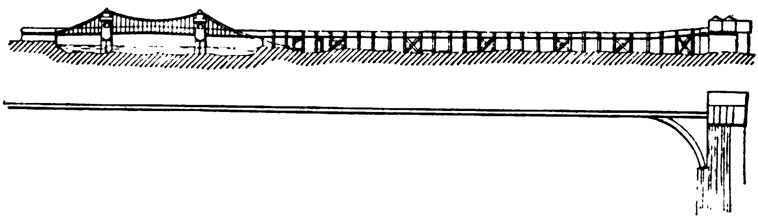
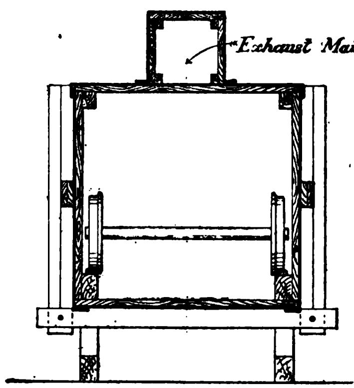
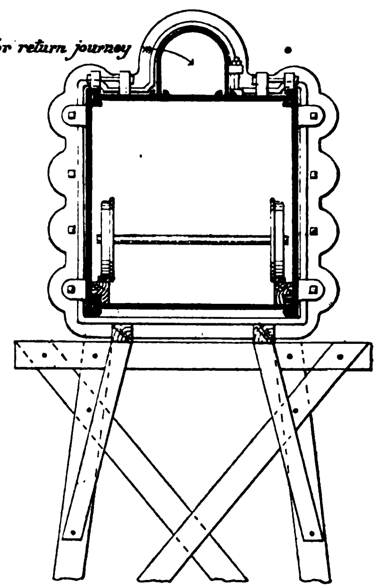


FIG. 20. *Section of Wood and Sheet-iron Tube over bridge.*

FIG. 21. *Section of Cast-iron Tube between the bridge and station.*



Vallance's (Medhurst's) system of Atmospheric Railway was really put to work in 1861, in the case of the "Pneumatic Postal Despatch," which was, in that year, laid down experimentally in Battersea Fields. A ⌂-shaped tube, 2 feet 9 inches high by 2 feet 6 inches wide, was employed. The tube contained a piston, to which were attached a number of trucks forming the train, to be filled with postal bags. In 1863 a line on this system was laid and got to work from Euston

to the Holborn Post Office, a distance of about one mile and a half, with the intention of going forward another mile to the General Post Office. In this case the ⌂-shaped tube was as much as 4 feet high by 5 feet wide. The trains were "blown" and "sucked" backwards and forwards. A vacuous or a pressure condition of a few inches of water was found sufficient for the propulsion. It cannot be said that this was not a passenger railway, for several gentlemen, including Mr. Clarke Hawkshaw, had the hardihood to treat themselves as parcels and to make the journey. This system was used for some time as far as Holborn, but, owing to station difficulties at St. Martin's-le-Grand, it was never put into operation there. All working was ultimately given up, and the machinery was removed. The tube itself is still *in sitû.*

In the year 1839, Samuel Clegg patented (No. 7,920) the Atmospheric Railway System, as commonly understood and put in practice, and, in the year 1840, an experimental length was laid down at Wormwood Scrubs.

In 1842, the report of Messrs. Smith and Barlow led to the system being tried on the Kingstown and Dalkey line; in 1843 Mr. (Sir) William Cubitt, determined to use it on the Croydon line; and, on the 19th August 1844, Mr. Brunel wrote to the directors of the South Devon line, recommending the adoption of the atmospheric system.

The South Devon Railway, it need hardly be said, extends from Exeter to Plymouth, along the right bank of the River Exe, until the seashore is reached, then along that shore to Teignmouth, up the left bank of the Teign to Newton Abbot, and from there to Totnes and Plymouth. There were pumping-engines at Exeter, Countess Weir, Turf, Star Cross, Dawlish, Teignmouth, Summer House, and Newton: eight engines in about 20 miles, so that the average distances between the engine-houses would be a little under 3 miles. The section, Fig. 22, page 316, shows that, while from Exeter to Newton the line was fairly level, there occurred on each side of the Dainton Tunnel heavy inclines of a mile and a half, or two miles in length, and having gradients ranging from 1 in 40 to 1 in 97. It will also be seen that, on going out of

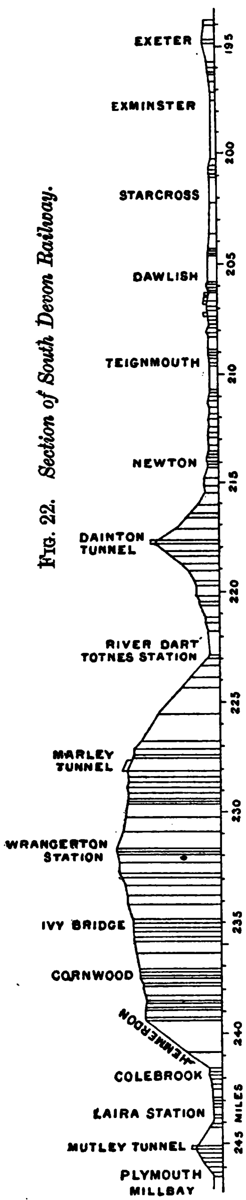



Fig. 22. *Section of South Devon Railway.*

Totnes, there is a very heavy gradient, part of it as much as 1 in 51; and again, a steep gradient at Hemmerdon of as much as 1 in 42, and less gradients at the Mutley Tunnel, near Plymouth. Brunel's great temptation to use the atmospheric system was that by getting rid of the weight of the locomotive, and by employing larger atmospheric tubes on the gradients, he hoped to be able to deal with inclines of this kind, and thus make a cheaper line. Moreover, he persuaded himself and a Select Committee, which sat in March and April 1845, to believe that a single line on the atmospheric system would do as much train-work as a double line on the locomotive plan, and the comparative estimates of cost were based on this view of the greater output of work by the atmospheric line. The atmospheric system was actually laid down nearly the whole way from Exeter to Newton. This was accomplished by 1846, but great difficulties were experienced with the pumping engines and machinery, a detail in which no trouble had been apprehended. It is not clear what was the nature of the difficulties. The engines had been provided by Messrs. Boulton and Watt, Messrs. Maudslay, and Messrs. Rennie; but on the 27th August 1847 Brunel reported to the South Devon shareholders that the line was being worked by locomotives, while the atmospheric was being got into order. On the 1st September 1847 it was resolved not to extend at present the atmospheric system beyond Totnes. On the 8th September it was reported that four atmospheric trains ran each way daily. In

the life of Brunel, it is stated that 865 horse-power were actually required to do the work, that he had a right to expect would have been done by 300 horse-power. By August 1848 the valve had begun to fail throughout its length. The cost had been £1,160 per mile, and on the 19th August 1848, just four years to a day after Brunel had advised the trial of the atmospheric, he reported that he did not recommend its extension, and, in fact, suggested it only as an assistant, on inclines. The directors then suspended operations, and, after the 9th September 1848, locomotives were used throughout.

The system, as is probably well known to all present, consisted (Figs. 23 to 26, page 318) in laying a continuous cast-iron tube A, on the sleepers between the rails, which tube had a valve-covered slit the whole way along the top.

The piston B, Fig. 23, was placed in the tube, and an arm C, from an attachment to the rear of the piston, came out through the slit and under the valve G, Fig. 26, and was then attached to the leading carriage of the train—a species of brake-van, which also carried passengers. The valve G, that covered the slit, was in the form of a continuous belt secured at one edge to the cast-iron tube, but capable of being lifted at the other edge. This belt was strengthened by wrought-iron plates above and below, Fig. 25. Assuming the valve to be closed, and to be air-tight, and the exhausting pumps to be at work, there would be produced a greater or less vacuous condition along the whole length of the pipe, and the belt-valve being lifted by rollers H, Fig. 23, at the rear of the piston, an opening was thus provided which allowed the connecting arm C to pass, and also allowed the atmospheric pressure to be readily exercised upon the piston area, giving (according to the amount of exhaustion) a pressure of about 8 to 10 lbs. per square inch.

It would appear, from the evidence taken before the Parliamentary Committee in 1845, that as many as three sizes of tube were proposed for conjoint use on the South Devon Railway—13-inch, 15-inch, and 22-inch—and that Brunel was designing an expanding piston, so as to be capable of going from one size tube to other sizes; but it would seem that, upon the comparatively easy portion

South Devon Railway.

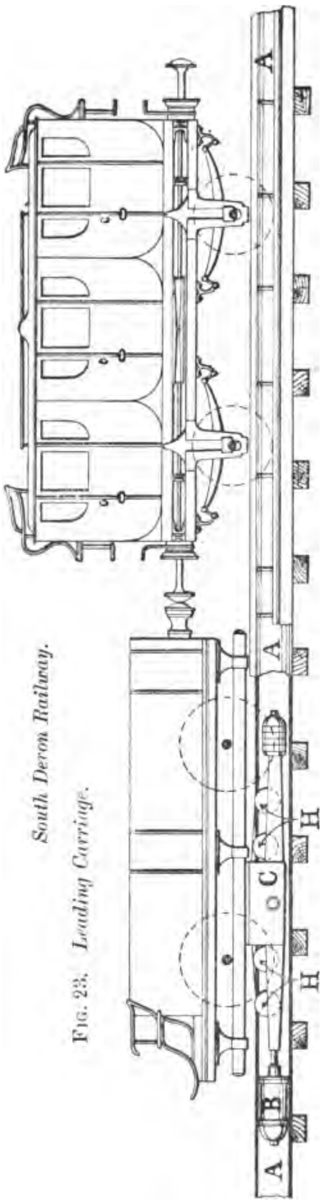



FIG. 23. Leading Carriage.

Tube, Valve, etc.

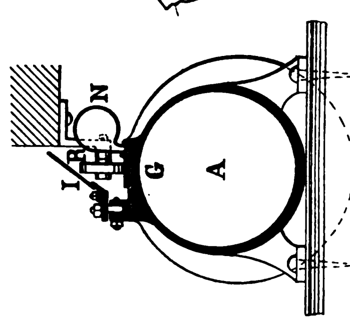



FIG. 24.

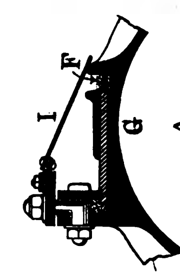



FIG. 25.

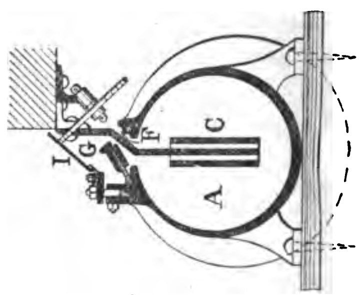



FIG. 26.

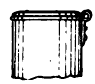


FIG. 27.

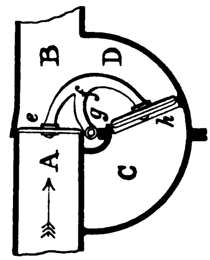



FIG. 28.

of the line which was actually laid, a tube of only 13 inches was employed. Taking the 13-inch piston there would be given at 10 lbs. effective a pull of some 12 cwt. The travelling was most luxurious. No noise, no smoke, no cinders, no smell.

It is easy to see how, as the rollers H, Fig. 23, attached to the piston went along, they would raise the valve, so as to allow of the passage of the arm from the inside to the outside of the tubes; but it is not so easy to see how the valve, which had been readily raised, could be as readily and securely bedded air-tight again.

The shutting of the valve was done by means of a roller R, Fig. 24, pressing it downwards into a seating of beeswax and tallow, F, Fig. 25, which it was sought to make sufficiently soft by a charcoal fire heater N, about 5 feet long, supported and running along with the carriage which had pressed the valve down. Above the valve there was a cover I, Fig. 25, formed of thin iron plates, hinged with leather, to protect the valve from snow and rain.

Sometimes the valve closed sufficiently air-tight, sometimes it did not; and when it did not, the engine pumped on in vain, while the train had to wait, helpless, at the station.

All sorts of valve schemes were proposed, and as many as seventeen patents dealing with the matter were taken out during the years 1844 and 1845.

It has already been said (page 315), the line was separated into sections of about 3 miles, each having its own exhausting engines.

To enable the train to pass from one section to another, valves, as shown in Figs. 27 and 28, were employed. Shortly before leaving the section along which the train had been travelling, the piston passed over the inlet to the exhaust-pump, went on by its momentum, compressed the remaining air in front of it, until it opened the valve, shown at Fig. 27, against the atmosphere.

The train then travelled, as shown by the arrow, into the end A, at Fig. 28, where it found in front of it a valve *e*, carried by a frame *f*, hinged at *g*. The lower end of *f* carried a piston valve *h*, of somewhat greater area than *e*. The line tube to the right hand B, was exhausted in readiness for the train, the superior area of *h* keeping the valve *e* closed, there being a connection between C and

the atmosphere. On the approach of the piston, the train moved a slide valve, so as to cut off the atmosphere from C, and to put C into connection with the vacuous condition. Thereupon, the pressure being taken off the valve *h*, the valve *e* yielded to the weight of the atmosphere and fell down, clear out of the way of the piston.

After working on the Croydon line from 1845 for a comparatively short time, the system had to be abandoned.

After working on the South Devon line (for a portion of it only) from some time in the year 1846 to some time in the year 1848, the system there, as has already been said, was abandoned.

After both the Croydon and the South Devon lines were given up, the atmospheric system worked for very many years (until 1855), between Kingstown and Dalkey, and up to even a later date in France, at St. Germain.

It is believed that there is not now any line on this system in existence.

Although the Electric Telegraph had been contemplated for the South Devon line, as being a most important adjunct for working a railway on the atmospheric system, it was not ready until the determination to abandon the system was being considered.

It can easily be understood with the line in sections, each section having to be exhausted in advance of the approach of the train, that if there were no telegraph, the only safe method of working would be to exhaust the section according to a time-table, and to keep it exhausted until the train really arrived.

Now, it appears it was contemplated that three minutes would suffice to exhaust a section, but it commonly took five, the difference being presumably due to leakage; and thus, if a train were ten minutes late, this leakage went on for fifteen minutes instead of five, involving ten minutes' extra expenditure of engine power.

It seems incredible to suppose that the valve could be made quite tight along its whole length. When it is considered that in a three-mile section there are 190,080 inches, so that $\frac{1}{1000}$th of an inch opening, continued for the whole length, would give an area of 190 inches, equal to rather more than a 15-inch pipe, the difficulty of obtaining absolute air-tightness appears very great indeed.

It thus became most important, for the economical working of the system, that the exhausting engine should be started as and when needed, having regard to the actual arrival of the train, as signified by telegraph, and not in mere obedience to a time-table.

When to the leakage loss there is added that due to the heating of the air (even after allowing for the reduction which may be made by injection into the pumps, or by jacketing them with cold water), the percentage utilised of the power expended is probably very low.

It will be remembered that, in Brunel's life, it has been stated that he found 865 horse-power exerted only yielded 300 horse-power, not quite 35 per cent. effective.

To set against this, there are, no doubt, important savings arising from replacing the great weight of the locomotive and tender by the comparatively trifling weight of the piston and leading brake-carriage: the ability to use lighter rails, owing to the absence of the locomotive: and the greater length of time for which these rails would last.

The writer was almost a daily traveller, for many years, upon the Blackwall Railway, when worked by ropes, and he distinctly remembers the practical immunity of the original iron rails of the Blackwall line from wear, as long as locomotives were not used.

Although the result has been failure, and although, in these days of electric possibilities, it is not likely anyone will revive the South Devon Atmospheric System, nevertheless, the writer thinks Mechanical Engineers will agree that a grateful recollection of the practical trial should be cherished, and that their thanks (tardy as they are after half a century) are due, with interest for the delay, to Isambard Brunel and to the Directors of the South Devon Railway, for having (wisely, as the writer thinks, notwithstanding the result) essayed, on a large and working scale, such a promising and delightful system of railway journeying as Clegg and Samuda's Atmospheric Railway.

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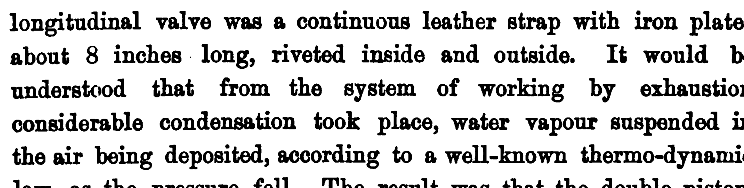
*Discussion.*

The PRESIDENT moved a vote of thanks to the author, which he said would be included in the Proceedings of the Institution.

The motion was carried by acclamation.

Mr. VAUGHAN PENDRED said that in 1852 and 1853 he was living at Dalkey and during that time took a great deal of interest as a lad in the Atmospheric Railway, and used to travel sometimes twice a week on it. The principal difference between the arrangement shown on Figs. 23 to 26, page 318, and the Dalkey line was that there was no metal covering-plate whatever to the slot in the 15-inch *pipe*, Fig. 29, and there was no wax used to keep the joints tight. The

*Kingstown to Dalkey Atmospheric Railway.*
Fig. 29. *Diagrammatic sketch of Piston-carriage, etc.*



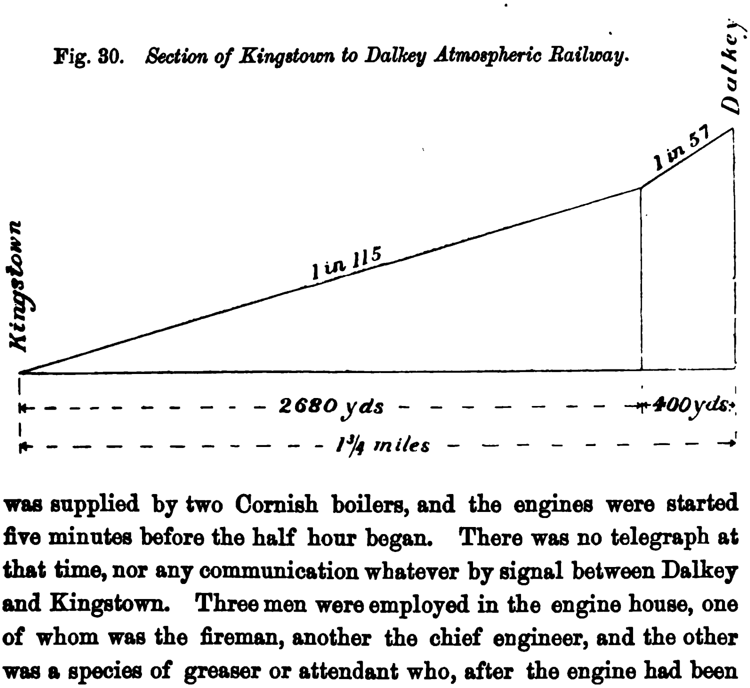

longitudinal valve was a continuous leather strap with iron plates about 8 inches long, riveted inside and outside. It would be understood that from the system of working by exhaustion considerable condensation took place, water vapour suspended in the air being deposited, according to a well-known thermo-dynamic law, as the pressure fell. The result was that the double piston, the leather, and everything connected with it, were always wet, and the wet leather was found to make a joint sufficiently tight. At all events he had never known an instance in which the line did not work because of the failure of the joint. A man who worked upon this Atmospheric Railway informed Mr. Cronin, his present

superintendent, that the leathers in the pistons were made of best butt leather, and usually lasted from six to eight months.

The PRESIDENT asked what was the length of the line.

Mr. PENDRED said it was $1\frac{3}{4}$ miles, Fig. 30, and the gradient was about 1 in 103. The trains were hauled up by the atmospheric action, and they ran down by gravity. The trains ran every half hour. The pumping engine at the Dalkey end was a vertical engine, with a vertical pump and a fly-wheel in the centre between the two. Steam

Fig. 30. *Section of Kingstown to Dalkey Atmospheric Railway.*




was supplied by two Cornish boilers, and the engines were started five minutes before the half hour began. There was no telegraph at that time, nor any communication whatever by signal between Dalkey and Kingstown. Three men were employed in the engine house, one of whom was the fireman, another the chief engineer, and the other was a species of greaser or attendant who, after the engine had been started for five minutes, went to a window from which he could see when the train was coming up the incline, and told the engineer to stop the engine. The running time on the line was about three or three and a half minutes to five minutes. He had travelled at eighty miles an hour on this atmospheric line. The front van was not

(Mr. Pendred.)
arranged as shown in Fig. 23, page 318; it was a regular guard's van, which also carried third-class passengers. There were two carriages, a composite carriage and the brake-van in front. The gauge was 4 ft. 8½ ins., not 5 ft. 3 ins., which was now the Irish gauge, and the trains ran in connection with the Dublin and Kingstown trains. What was then the atmospheric railway had now become part of the Dublin, Wicklow, and Wexford system. The gradients had been flattened and there was no relic at all left of the old plant. One of the Cornish boilers was generally used to supply the steam, but sometimes both were used. The second one was generally understood to be a stand-by. They were worked on the slow-combustion system. The whole time during which the pump was at work was at the maximum ten minutes in each half hour; during the rest of the time the boiler was simply bottling up steam for use. The pressure was about 45 lbs. The engines were parallel motion engines and not slide guides. As well as he could remember, the stroke was about five feet, and the diameter of the pumping cylinder about three feet. It was possible that he might have some notes of that, but he could not give any precise data at the moment. On Sundays three coaches were put on and sometimes four, and then there was considerable difficulty in getting the trains to enter Dalkey terminus. Sometimes they did not go fast enough to run up the hill, because the pipe left off one hundred yards or so from the station. He had seen all the passengers turned out on the side of the embankment and compelled to push the train up before they could go any further. That was a species of Sunday work. The great feature about the line he thought was that it never broke down; it always worked. People were always sure of getting as far as the pipe went. He had never heard of an instance of the piston sticking and the train having to run back, and had never heard of an instance when the piston did not get out of the tube. When the train came up to Dalkey station, the guard put a lever on to the square end of the vertical bar passing through the floor of the carriage, Fig. 29, page 322, and swung the whole of the piston-carriage on to one side, where the bar was hooked. The train then ran back to Kingstown by gravity, the piston, &c., being outside the tube. The

train overran the tube a short distance, the piston-carriage was dropped, and the train allowed to run forward until the piston again entered the tube. The vacuum was measured by a mercury barometer, and he thought the average used to be on the Kingstown end about 8 lbs. or 16 inches. He might mention that at all times the valve leaked, although not much, but enough to make a sensible hissing noise, and if one were standing at the side of the line, one could always tell when the engine was started by hearing in the distance on a calm day a little hiss which came running all along the line, showing the gradual process of exhaustion in the pipe. Some people used to imagine that, as soon as the pumping began at the Dalkey end, a vacuum was obtained at the other end, but that was not the fact. It took about five minutes to exhaust the pipe sufficiently to start the train. He did not think there was anything more he need mention, but if there was any question any member might wish to ask he should be glad to answer it if possible.

The President asked if the line was fairly straight.

Mr. Pendred said it was not; there were many sharp turnings.

The President also asked how long the line continued to work.

Mr. Pendred thought it was mentioned in Sir Frederick Bramwell's Paper from about 1842 to 1855.

Mr. Arthur Norton asked what was the method employed in braking the train.

Mr. Pendred said there were ordinary screw brakes in the guard's van. He might mention that when the train came up very fast indeed with a light load, which was sometimes the case, the brake was applied long before the piston got out of the tube, but on one or two occasions the whole train ran through the station and right through the gates. He could not call to mind a case in which anybody was ever killed or seriously injured.

Mr. Henry Lea, Member
were bored, and if not, what
piston to travel.

Sir Frederick Bramwell
piston travelled by having an

Mr. Henry Davey, Member
fact in connection with the hist
Boulton and Watt at their Soho
machines from a central pumping
of energy described in the Paper.
Life of Nasmyth. Nasmyth, on
in 1830, found the system, wh
operation.

Mr. Bryan Donkin, Member
would kindly procure for the In
Dublin he had been good enough
possible to have a profile.

Mr. Pendred said he did not
found now.* It was possible there
doubted it. The line had been con
the present time it was entirely differe

Sir Frederick Bramwell, Bart.,
should mention that Clegg and Samud
under "Railways" but under "Valves."
they found that Medhurst, not in the pl
seal, but in the other plan of having a
top, had entirely anticipated them

* Fig. 30, page 323, has been kindly supplied
Carriage, and Wagon Superintendent of the Du
Railway.

communications between an internal piston and an external carriage. Medhurst did not disclose any mode of making that tube airtight when the valve was put down again, or how to put it down, and it would be found that the patent of Samuda confined itself to the mode of sealing the valve. With respect to the Medhurst patent, he wished to call attention to the fact that so long ago as 1810 Medhurst pointed out that, with a carriage running on iron rails each side of the tube, a speed of fifty miles an hour might be attained. Brunel persuaded himself, and a Committee of the House, that with a single atmospheric line as much work could be done as with a double line on the ordinary plan. He had no doubt that Brunel honestly believed it, but he, Sir Frederick, had never been able to follow it. He thought the directors were wise in adopting the system. They took the best advice of the day, and the system was already working to more than an experimental extent, and if it had answered, the result would have been a great deal better as compared with locomotive traction. The charm of travelling was not to be described. However, it did not answer, but he thought the men who agreed to use it must be judged by what they had before them at the time, and not by the result.

The PRESIDENT said that Mr. H. M. Brunel was unfortunately unable to be present, but he was sure Sir Frederick Bramwell would be glad if Mr. Brunel would add any contribution to the discussion in writing, Sir Frederick of course having the right to comment upon that contribution.

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Mr. H. M. BRUNEL wrote, referring to the chapter on "The Atmospheric System" contained in the "Life of I. K. Brunel," published in 1870, and added that he had no further remarks to offer on the atmospheric railway question.

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